UMEM Parameter Extraction

1. Introduction

This manual provides a detailed extraction procedure of UMEM. Most of the parameters in this model are decoupled for V>0 and V<0 regions.

2. RRAM

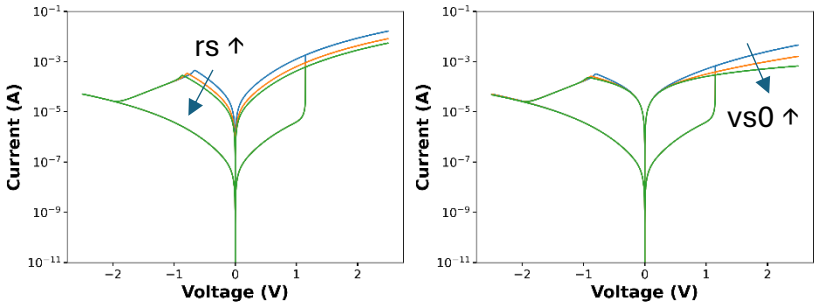
To use RRAM mode, please set devmod=0.

These are the parameters used in the demonstration.

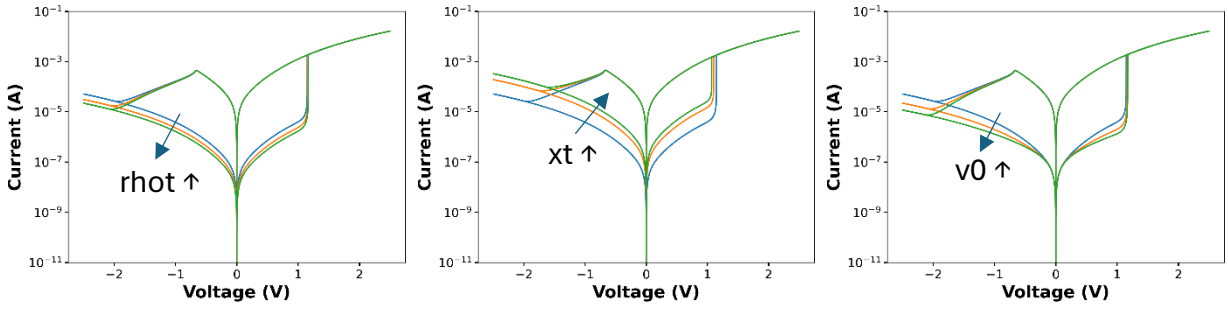
.model rram umem_va devmod=0 tm=1.69n area=25e-14 rth=5e5 cth=1e-15 x0=0.15n tau0=1e-15

+ ea0=1.24 ea0_r=1.24 am=0.8 am_r=0.5 a0=-0.1 b0=3 rhot=3e-3 v0=0.45 rs=4000 vs0=1 areanom=25e-14

First step is extracting the resistance parameters. This step can be applied to different device modes. To fit the on-state current, adjust rs for magnitude and vs0 for slope.



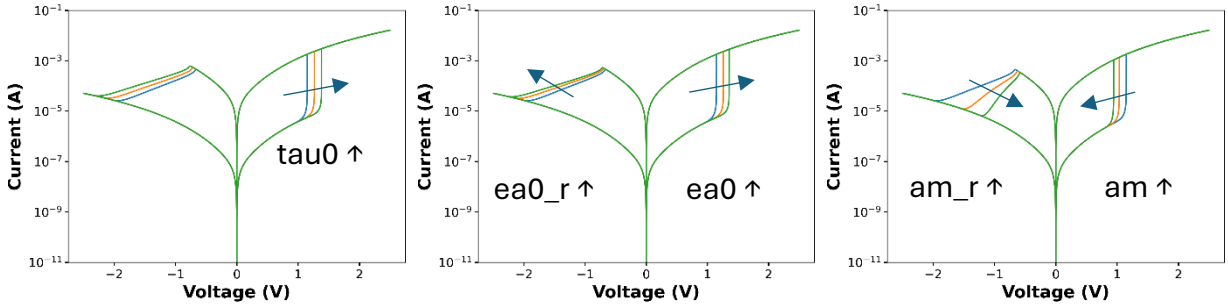
To fit the off-state current, adjust rhot and xt for magnitude and v0 for slope. xt controls the length dependence.



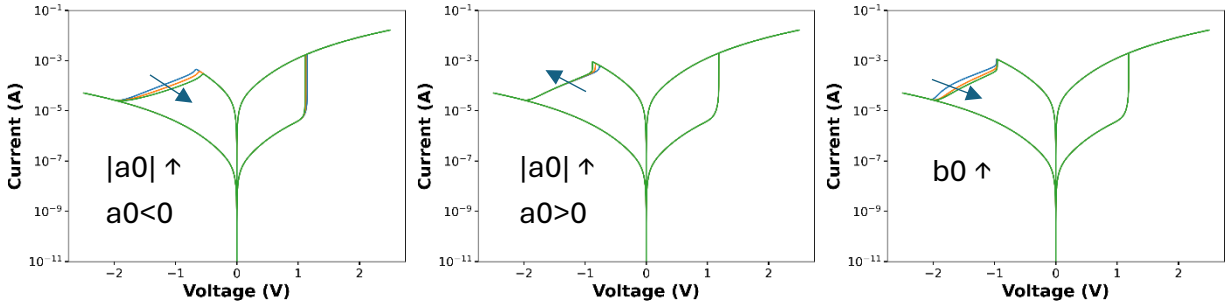
The next step is calibrating the SET and RESET switching.

Increasing tau0, ea0, ea0_r will increase the SET and RESET voltages.

Increasing am and am_r will decrease the SET and RESET voltages and increase the slope.



To change the slope of RESET transition, a0 and b0 can be adjusted. a0>0 and a0<0 will create different RESET behaviors. a0 and b0 will also affect the positive region which alter the state dependence of the SET voltage.



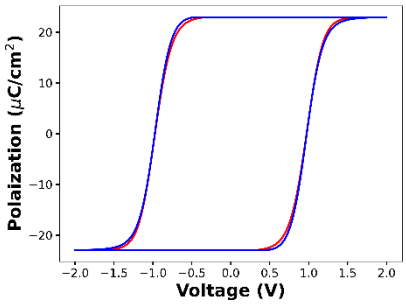
3. FERAM/FTJ

To use FE mode, please set devmod=1.

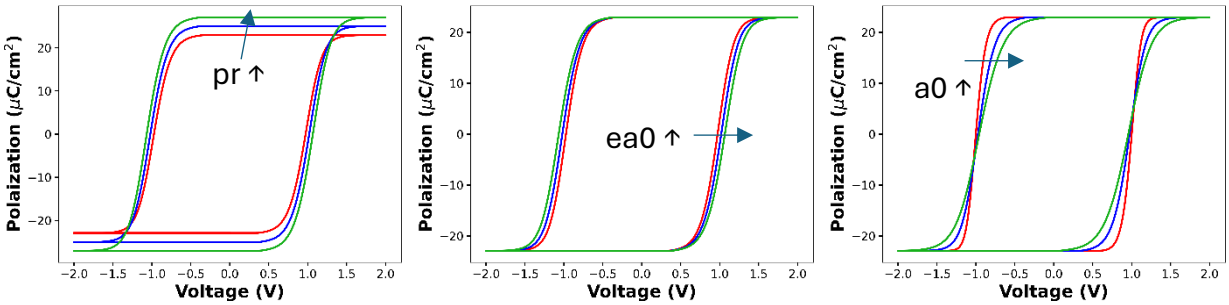
There are 2 distributions to choose from. pdfmod=0 is Gaussian (red). pdfmod=1 is log-normal (blue). For log-normal distribution, the transition region is asymmetric. There are more grains in the high E_A side with longer distribution tail. The following set of parameters are used for demonstrations.

.model fe umem_va devmod=1 pdfmod=0 tm=8.3n pr=0.229 tau0=400n ea0=2 a0=0.2 b0=2.0 am=3.4

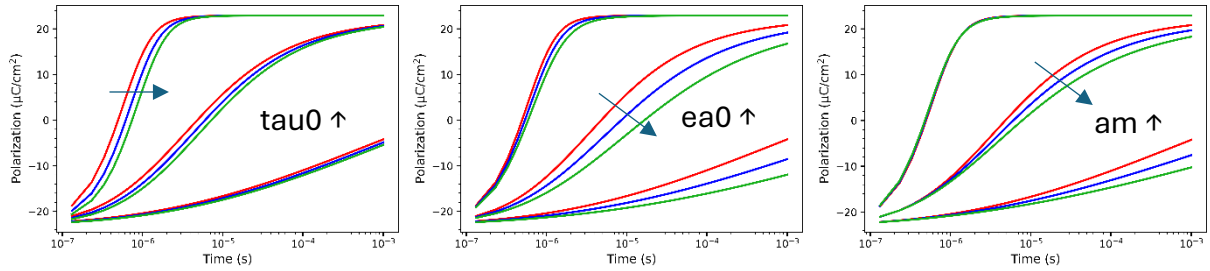
+md1=0.1 md2=5 epar=34 efb=1e7 rhot=1e-5 x1=0.2 v0=0.45

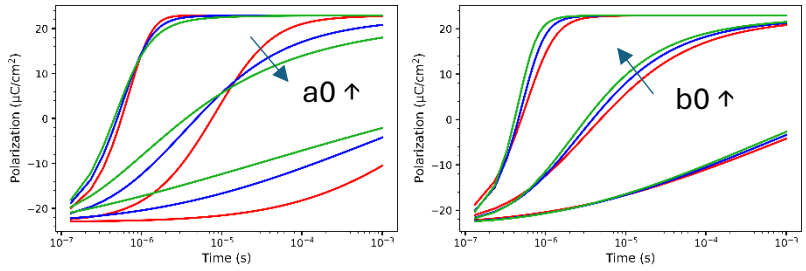


Major PV loop can be adjusted by 3 key parameters: pr, ea0, and a0. a0 controls the slope in the transition region.

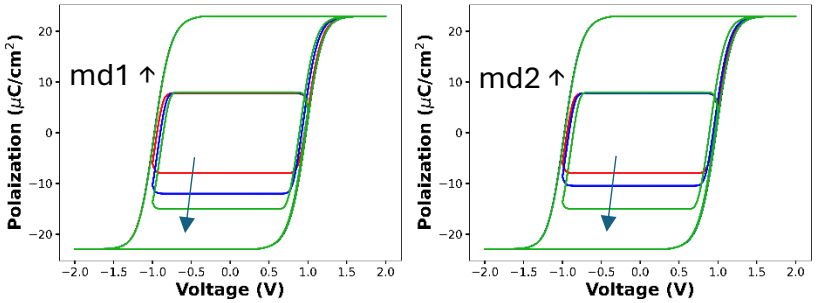


A more detailed extraction should be done by fitting P-t curves. tau0 shifts the delay. ea0 and am determine the voltage dependence of switching. ea0 shifts the entire voltage dependence while am tunes the space between each P-t curve. a0 can adjust the slope and final state the curve reaches. b0 can further increase the slope without changing other aspects of the curve.

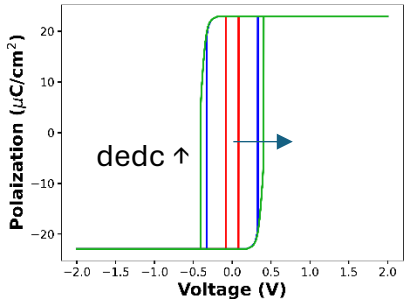




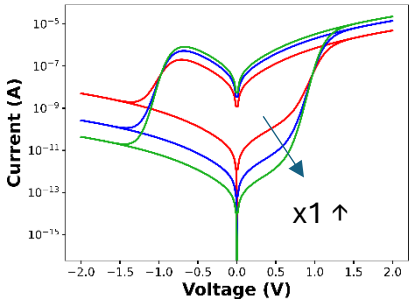
Minor loops can be tuned by md1 and md2.



In DC simulation, the hysteresis window is controlled by dedc. The maximum window size will be restricted by ea0.



For FTJ IV, the on-off current ratio is determined by x1. The other parameters can follow the RRAM case.



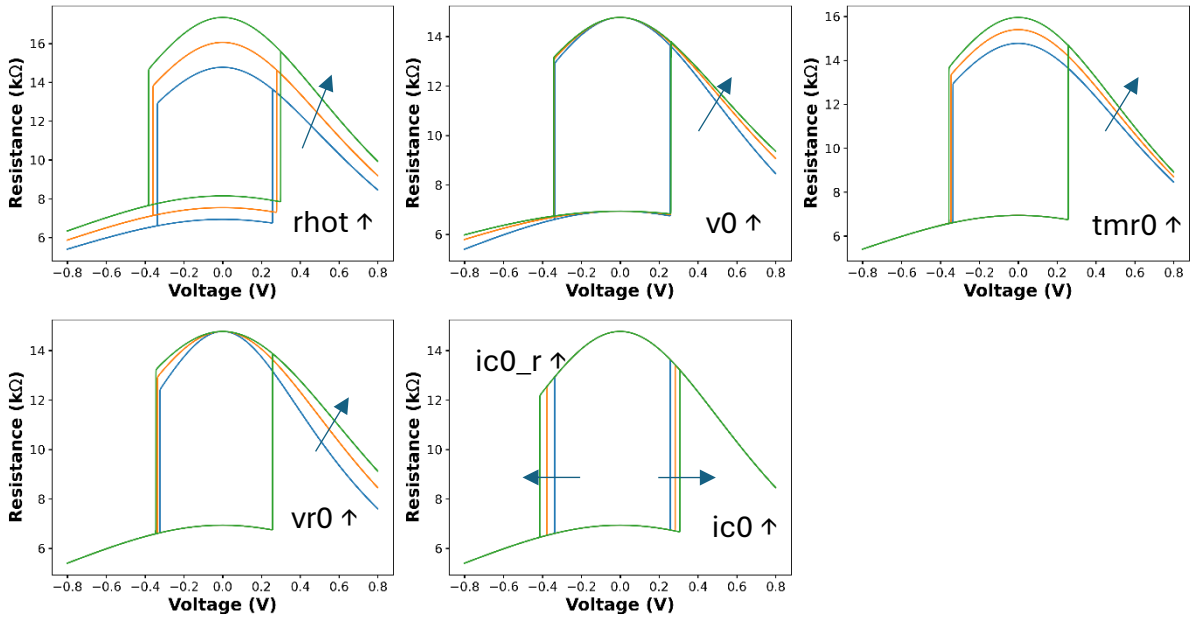
4. MRAM

To use MRAM mode, please set devmod=2.

This parameter set is used for demonstrations.

.model mram umem_va devmod=2 tm=1e-9 area=49e-16 areanom=49e-16 rhot=4.6e-3 ic0=3.8e-5 ic0_r=2.6e-5 v0=1.5 tmr0=1.13 vr0=0.8 tau0=1.8e-8 rs=0

To fit the RV curves, rhot or xt will affect not just the overall resistance level but also the switching voltage since I=V/R. v0 will change both the slope or on and off resistance. tmr0 controls the on-off ratio. vr0 only adjusts the slope of off resistance. ic0 and ic0_r determine the critical currents and switching voltages.



The pulse dependent Ic is adjusted by ic0/ic0_r and tau0. A simple parameter set is used as an example.

.model mram umem_va devmod=2 tau0=2.2e-9 ic0=120e-6

Blue line: nominal. Orange line: increase ic0. Green line: increase tau0. ic0/ic0_r will shift the curve. tau0 tunes the slope.